Light Scattering Studies
of Fractal Soot Aggregates in Flames

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This paper presents an overview of our work concerning light scattering studies of soot in flames.[1-4] We have developed static light scattering (SLS) to an ability where a complete in situ characterization of soot cluster morphology can be obtained. The morphological parameters we can measure are soot cluster radius of gyration, Rg, fractal dimension, D_f, number of monomers per cluster, N, and monomer radius, a.[2] We have also developed an SLS technique to measure the width of the size distribution.

Our methods include an optical structure factor measurement[1] in which the scattered intensity is measured as a function of scattering angle, an example of which is given in Fig. 1. In Fig. 1 $q = 4\pi\lambda^{-1} \sin\theta/2$ where θ is the scattering angle. For small qRg, $I \sim 1 - q^2R_g^2/3$ hence Rg is easily measured. For large qRg, $I \sim q^{-D_f}$ hence D_f can be easily measured if data are available in this regime. For general qRg, however, the detailed form of the structure factor depends on how the density of soot terminates at the cluster perimeter, the so-called cutoff function. This was previously poorly known but our recent work has refined our knowledge.[3,5]

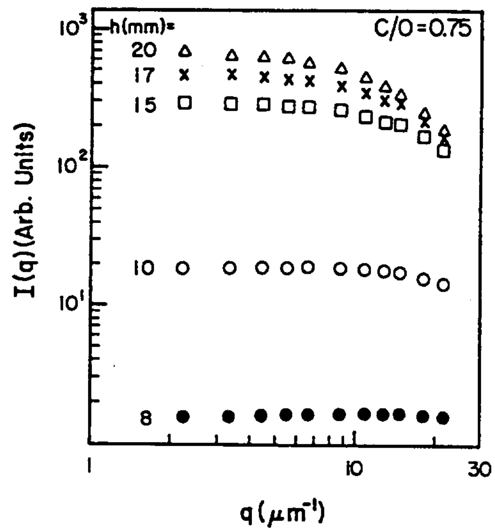

Fig. 1. Scattered light intensity $I(q)$ as a function of the scattering wave vector q for five different heights above burner h for the C/O = 0.75 flame.

A second measurement involves the classic scattering/extinction measurement. In this method an absolute measurement of the scattered intensity at small scattering angles is compared to the extinction of the light as it passes through the flame. This yields a volume equivalent sphere cluster size, the scattering/extinction radius R_{SE}, and cluster number density. We then use[2]

$$R_{SE} = aN^{1/3}$$

and

$$N = k_0 (R_g/a)^{Df}.$$

Given R_g and D_f from the optical structure factor measurement, and R_{SE} and the constant k_0, one can solve for N and a. Here again a heretofore poorly known quantity, k_0, had to be determined[5] with reasonable accuracy before this synthesis of methods could yield viable results.

We will illustrate this method using data obtained from premixed flames. We also compare our light scattering measurements to TEM measurements successfully. This not only supports the viability of our method but also indicates the optical theories describing scattering and absorbtion from aggregates must be valid. Currently we are beginning to study laminar diffusion flames and we hope to have data by the meeting time.

These new abilities for cluster characterization have opened doors to other important measurements. For instance we have used dynamic light scattering to measure the diffusion coefficient of fractal soot clusters and, knowing their morphology via SLS, have determined how the diffusion coefficient depends on morphology.[6] This will be important for subsequent studies of aggregation kinetics. We have also studied depolarized light scattering, shown it is a result of intracluster scattering, and found its morphological dependence.[7] This may lead to in-situ optical constants measurements.

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